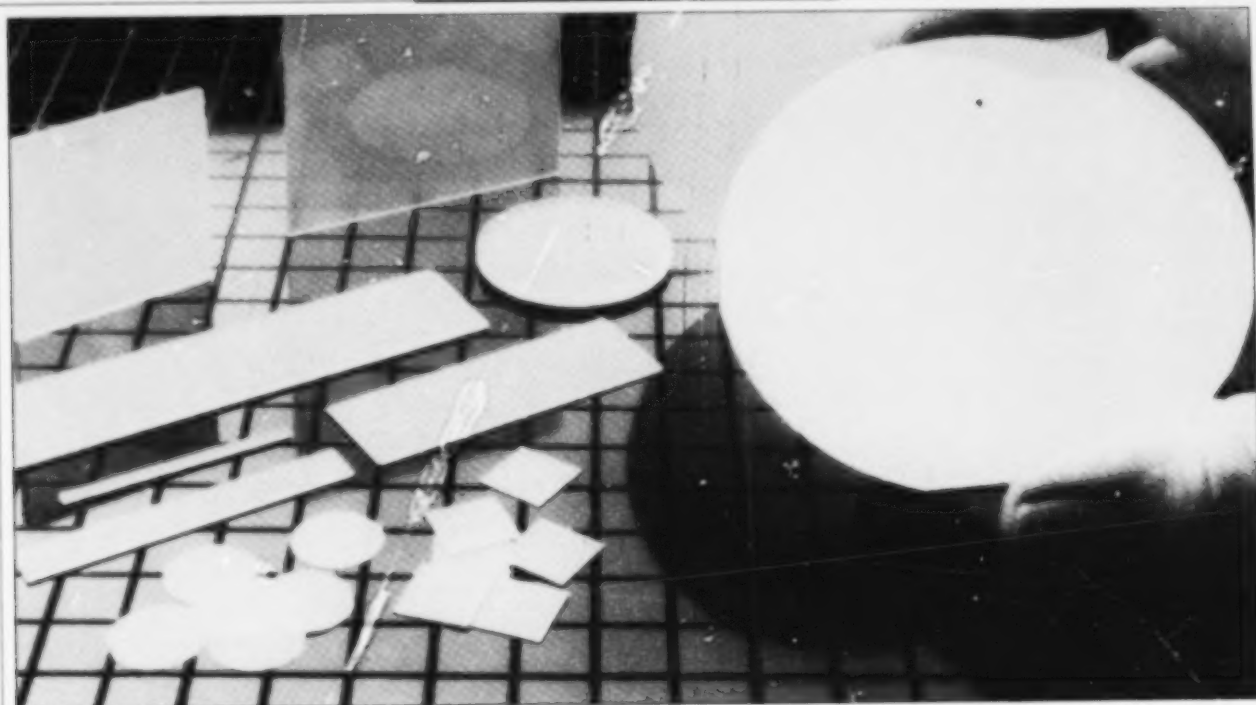


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ANNUAL REPORT



QUARTZ CRYSTAL

By Joyce A. Ober

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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QUARTZ CRYSTAL



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T S Ary
Director

September 1991

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COVER PHOTO:

Quartz crystal bars are cut into blanks of different sizes depending on final requirements. Final products must meet precise specification. (Photo is courtesy of P. R. Hoffman Materials Processing.)

For comments or further information, please contact
The Branch of Industrial Minerals
The Division of Mineral Commodities
U.S. Bureau of Mines
2401 E St., NW, MS 5209
Washington, DC 20241-0001
Telephone: (202) 634-1177
Fax: (202) 634-4091

QUARTZ CRYSTAL

By Joyce A. Ober

Mrs. Ober, a physical scientist with 13 years industry and U.S. Bureau of Mines experience, has been the commodity specialist for quartz crystal since 1986. Domestic survey data were prepared by Maureen Nash Riley, mineral data assistant.

Cultured quartz crystal production and consumption decreased slightly in 1990 after 3 years of growth. Consumption of domestic lascas as feedstock for cultured quartz crystal decreased also. The single domestic producer of lascas, the raw material from which cultured quartz crystal is produced, operated its mine to supply material to domestic consumers. Demand for specimen-quality natural quartz continued; quartz crystal for this application is discussed in the Gem Stones chapter.

Electronic-grade quartz crystal is single-crystal silica that is free from all visible defects and has piezoelectric properties that permit its use in electronic circuits for accurate frequency control, timing, and filtration. These uses generate about all the demand for electronic-grade quartz crystal. A smaller amount of optical-grade quartz crystal is used as windows and lenses in specialized devices, including some lasers.

More natural quartz crystal was consumed in electronic and optical applications until 1971, when cultured quartz crystal took the lead. Since that time, cultured (synthetic) quartz has replaced practically all natural crystal in these applications. In 1990, synthetic quartz crystal producers consumed about 527,000 kilograms of lascas in their production, and less than 400 kilograms of natural quartz crystal found application in electronic devices.

DOMESTIC DATA COVERAGE

The U.S. Bureau of Mines collected domestic production and consumption data for quartz crystal through a voluntary survey of U.S. operations. Six companies responded to the canvass for the production of cultured quartz crystal, and

the five active operations represented 100% of total production shown in table 1. Of the 34 operations canvassed concerning consumption of quartz crystal, 32 responded, 7 of which did not consume quartz crystal in 1990. These companies represented approximately 100% of total consumption, also shown in table 1. Consumption for the nonrespondents was estimated using reported prior-year consumption levels.

ANNUAL REVIEW

Legislation and Government Programs

The National Defense Stockpile contained about 686,000 kilograms of natural quartz crystal, valued at about \$9 million at yearend. This quantity represented an excess of about 577,000 kilograms above the goal set for the stockpile.

TABLE 1
SALIENT U.S. ELECTRONIC AND OPTICAL-GRADE QUARTZ CRYSTAL STATISTICS

(Metric tons unless otherwise specified)

	1986	1987	1988	1989	1990
Production:					
Mine ¹	544	—	272	454	423
Cultured	238	381	389	464	441
Exports:					
Natural: ²					
Quantity	34	63	43	NA	NA
Value thousand dollars	\$411	\$708	\$431	NA	NA
Cultured: ²					
Quantity	147	203	189	57	39
Value thousand dollars	\$5,686	\$6,954	\$7,162	\$2,600	\$1,745
Lascas:					
Quantity	—	—	—	—	—
Imports of lascas: ³					
Quantity	24	66	98	NA	NA
Value thousand dollars	\$51	\$157	\$180	NA	NA
Consumption:					
Natural (electronic and optical-grade)	1	(⁴)	2	(⁴)	(⁴)
Cultured (lumbered)	20	25	28	17	14
Cultured (as grown)	194	250	293	344	326
Total	215	275	323	361	340

¹Estimated. NA Not available.

²Excludes lascas produced for specimen and jewelry material uses.

³Bureau of the Census as adjusted by the U.S. Bureau of Mines.

⁴Bureau of the Census.

⁵Less than 1/2 unit.

During the year, quartz crystal stockpile sales amounted to about 172,000 kilograms at about \$444,000. About one-quarter of the disposals was to support the stockpile ferroalloys upgrading project. The excess stockpile material, which primarily consists of large natural crystals, could be absorbed by the specimen and gem material industry. Very little, if any, of the material would be consumed in the same applications as synthetic quartz crystal.

Strategic Considerations

Natural electronic-grade quartz crystal was initially designated as a strategic and critical material after World War II. Cultured quartz crystal was not commercially available at the time of U.S. stockpile acquisition. With the changing patterns of quartz consumption, the Federal Emergency Management Agency asked the National Materials Advisory Board to assess the requirements and related trends for stockpiling quartz. The final report was published in early 1985 and recommended changes in stockpile goals to reflect the declining dependence on natural quartz crystal.¹ The President has set the quartz crystal goal for the stockpile at 110,000 kilograms.

The National Defense Stockpile contains natural quartz in several weight classes and grades, including about 13,000 kilograms of material consisting of individual crystals weighing more than 10,000 grams each. Some of the individual quartz pieces in this weight class are suitable for generating mother seeds for cultured quartz crystal production. These large pieces were acquired from Brazil because similar materials were not available domestically.²

Production

Coleman Quartz Inc., Jessievile, AR, the only domestic company known to produce lascas, supplied the feed material for cultured quartz crystal from mine production. Production in 1990 was about 7% lower than that in 1989. Coleman mined only during the summer months, but processed lascas year round. Lascas was mined, crushed, and sized. Crushed and sized material was transported to the processing plant where operators rinsed it in oxalic acid and then in deionized water to remove external contaminants. Hand sorting, drying, and examination on a light table completed the

necessary processing. The material was then shipped to cultured quartz crystal producers in 45-kilogram (100-pound) bags.

Production of cultured quartz crystal decreased almost 5% in 1990. Five companies were active. The two largest producers, Sawyer Research Products Inc. of Eastlake, OH, and Thermo Dynamics Corp. of Merriam, KS, were independent growers that produced crystal bars for domestic and foreign consumers in the crystal device fabrication industry. Motorola Inc. of Chicago, IL, produced quartz crystal for both internal consumption and the domestic device fabrication industry. P. R. Hoffman Material Processing Co. of Carlisle, PA, also reported outside sales. Bliley Electric Co. of Erie, PA, produced only for internal consumption. Electro Dynamics Corp. of Overland Park, KS, formerly a producer, sold the quartz-crystal-growing portion of its operation to Thermo Dynamics in February 1989. Electro Dynamics continued to process synthetic quartz crystal.

These companies produced cultured quartz crystal using a hydrothermal process in large pressure vessels, known as autoclaves. Seed crystals, very thin crystals cut to exact dimensions, were mounted on racks and suspended in the upper growth region of the vessel. Lascas was loaded in an open-mesh wire basket that was placed in the bottom of the autoclave.

A solution of sodium hydroxide or sodium carbonate (the mineralizer), with additives such as lithium salts, and deionized or distilled water was used to fill the vessel to 75% to 85% of its volume. The bottom half of the growing vessel was heated to temperatures averaging between 350° to 400° C; the temperature of the top portion is maintained at 10° to 50° C less. At these temperatures, the solution expands and creates an internal pressure in the vessel of between 10,000 pounds per square inch and 30,000 pounds per square inch. Under these conditions, the lascas dissolves to create a solution saturated with silica.

Through convection, the saturated solution transports dissolved silica to the cooler upper half of the vessel where it becomes supersaturated, and the excess dissolved quartz deposits on the seed crystals in the top half of the autoclave. The process continues until the growing crystals reach desired size. The process may take 30 to 60 days and sometimes even longer.

The processing of quartz crystals for various end uses is the same whether natural or cultured crystal is used. Crystals are examined for physical defects before cutting. They are then cut, usually with diamond or slurry saws, along a predetermined crystallographic plane to a thickness slightly larger than that desired. Each wafer is inspected and diced into blanks of the desired dimensions. The blanks then progress through a series of lapping stages until they reach the final thickness; electrodes are attached, and the crystals are mounted in suitable holders. The final assembly, called a quartz crystal unit, is ready for insertion into an electronic circuit.

Consumption and Uses

Consumption of lascas by the five domestic quartz crystal producers decreased about 8%, from 572,000 kilograms in 1989 to 527,000 kilograms in 1990. The 25 active device-fabricating companies in 9 States consumed 8% less quartz crystal in 1990 than in 1989. Of these companies, 24 consumed only cultured quartz crystal. One company consumed only natural quartz crystal.

Lascas and quartz crystal were used in piezoelectric, optical, and glass industries. The piezoelectric effect is achieved when a suitable electrical signal is applied to a quartz wafer or blank with appropriate electroding, which causes the wafer to vibrate mechanically throughout the bulk of the material at a characteristic natural resonance frequency. The quartz resonators are uniquely suitable for military-aerospace and commercial band-pass filter applications that require very high selectivity or in oscillator applications that require very high stability. In addition, for many applications requiring only moderate stability, a quartz resonator offers a unique combination of high performance, small size, and low cost. Quartz resonators were used for many less demanding applications such as providing timing signals for watches, clocks, and microprocessors in a variety of industrial, automotive, and consumer products.

The quartz wafer becomes too thin for practical use for very high frequencies (above 100 megahertz). Quartz crystal structures that use surface vibrations, in which the frequency is determined by electrode dimensions rather than wafer thickness, have become more important at these high frequencies. These structures

are called surface acoustical wave (SAW) devices. Most optical applications used quartz in the fused form as silica glass. Relatively small quantities of cultured quartz crystal were used directly for special optical considerations. Quartz's crystal properties are responsible for its uses that deal with normally polarized laser beams. Quartz retardation plates (especially quartz wave plates), Brewster windows and prisms, birefringent filters, and tuning elements are used in laser optics.

Historically, quartz crystal has been a material of strategic importance. During World War II, quartz was used principally in analog communications (e.g., in telephone multiplexing and in mobile military radios). Today, because of military emphasis on command, control, communications, surveillance, and the growth of more sophisticated electronic systems, the importance of quartz crystal devices has grown. Many of the military applications are at the leading edge of technology. It has been U.S. Department of Defense policy to require all military systems to be hardened to nuclear radiation. To meet this special requirement, cultured quartz crystal must be radiation hardened by sweeping, a technique to remove certain impurities from the quartz.

Cultured quartz was used almost exclusively by the crystal device industry because of cost advantages. For resonator applications, raw quartz must be cut into thin wafers oriented precisely with the raw material crystal axes. The uniformity and convenience of cultured quartz have made its use almost universal. Unlike cultured quartz, natural electronic-grade quartz requires special orientation, cutting, grading, and sizing to produce a quartz wafer. As a result, most device manufacturers that cut natural quartz in the past have discontinued its use. One of the remaining uses of natural electronic-grade material was in pressure transducers used in deep wells.

Stocks

Crystal growers' stocks of as-grown cultured quartz crystal were reported as 76,000 kilograms at the beginning of 1990. At yearend, these stocks had increased to 97,000 kilograms.

Prices

The average value of as-grown cultured quartz, based on reported sales of about 324,000 kilograms, was \$28.35 per kilogram (\$12.86 per pound), a decrease of about 8% compared with that of 1990. Sales volume decreased about 5%. The average value of lumbered quartz, as-grown quartz that has been processed by sawing and grinding, decreased 24% to \$107.48 per kilogram (\$48.75 per pound), based on reported sales of 33,000 kilograms. Sales volume decreased 16%.

Foreign Trade

The Bureau of the Census began using the Harmonized Tariff Schedule in 1989 to identify material passing through U.S. customs. This system makes classification codes for imports and exports consistent internationally. With the adoption of the new codes, imports and export codes for quartz crystal changed, and some formerly listed details are no longer available. The import code for Brazilian crude pebble, which represented approximately all lascas imports recorded, was eliminated. Although this material probably continued to enter the United States, the new code system aggregated several categories, making information about specific materials unavailable. The export data for natural electronic-grade quartz crystal were no longer available.

Because of these changes, foreign trade information for quartz crystal is limited. While information remained concerning exports of synthetic quartz crystal, Census figures indicate a continuing downward trend for quartz crystal exports. Reports by domestic producers indicated that these data may not be accurate. Reports indicated that exports were higher than those reported by the Census Bureau.

World Review

Synthetic quartz crystal production is concentrated in the United States and Japan, with several companies producing crystal in each country. Smaller production capacity exists in Belgium, Brazil, Bulgaria, France, Germany, the Republic of South Africa, and the United Kingdom. Details concerning quartz

operations in China, the U.S.S.R., and other Eastern European countries are unavailable.

Alfa Quartz C.A., a joint venture between Bulgarian and Venezuelan companies, was building a cultured quartz crystal plant near Caracas, Venezuela. On completion, the operation should have the capability of producing 36,000 kilograms of quartz crystal per year from 16 autoclaves. Sales are expected to be lumbered bars and blanks. Domestic lascas deposits will provide feed material.

OUTLOOK

Domestic production of cultured quartz crystal has grown or remained relatively stable since 1986. The slightly decreased production in 1990 is not expected to represent the beginning of a downward trend. Demand for crystal devices for electronic consumer products and microprocessor-controlled devices should continue to grow, and quartz crystal production should remain strong well into the future. Because crystal devices continued to be used in an increasing variety of applications from kitchen appliances to military hardware in addition to the traditional items such as watches, demand should continue to increase, and additional production capacity may be required worldwide.

¹National Materials Advisory Board, Quartz for the National Defense Stockpile, Natl. Acad. Sci., Washington, DC, NMAB-424, Jan. 1985, 99 pp.

²Work cited in footnote 1.

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